

The Integration of Modeling and Simulation with Joint Command and Control on the Global Information Grid

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ABSTRACT: *As documented in the Joint Command and Control (JC2) Capability Development Document (CDD), JC2 will require M&S capabilities to support a multitude of functions including course of action analysis, planning, mission rehearsal, and training. This will necessitate the integration of M&S with JC2 on the Global Information Grid (GIG), the net-centric information environment of future warfighting. DISA has been successfully experimenting with net-centric capabilities of the GIG through Net-Centric Enterprise Services (NCES) prototyping efforts such as the Blue Force Tracking Service and the Global Force Management Service. Similarly, the M&S community has been successfully experimenting with the implementation of M&S in a net-centric information environment (the web) using many of the same technologies through the Extensible Modeling and Simulation Framework (XMSF) effort.*

This paper leverages the work of the NCES program and the XMSF community to explore how M&S and JC2 can be integrated in the GIG environment using web-based technologies and standards. Specifically, it will address the structure and content of XMSF profiles to enable composable, reusable, and interoperable M&S and JC2 capabilities. It draws from previous work on XMSF, M&S composability, and M&S to C4I integration as well as NII and DISA guidance such as the GIG CRD, the Net-Centric Data Strategy, and the Net-Centric Operations and Warfare Reference Model. Although some aspects of the paper are U.S. Army-centric, the principles are easily applicable to joint and combined forces.

1 Introduction

The U.S. Army defines Battle Command as the "art and science of applying leadership and decision making to achieve mission success". [35] Army Battle Command is supported by a myriad of Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance (C4ISR) systems, and simulation to C4ISR interoperability has been an important aspect of Army Battle Command since the Force XXI Battlefield Digitization Program was initiated in 1994 and the introduction of the first "digital division" in December, 1995. Simulation to C4ISR interoperability is essential for testing C4ISR components, for training battle staffs on

the use of digital battle command systems, and for conducting large-scale Live-Virtual-Constructive training events at the Army's Combat Training Centers, including the National Training Center at Fort Irwin, CA. Simulation to C4ISR interoperability is also important to the other Services and the Joint community, and is a key component of the Air Force Blue Flag exercise series, Navy Fleet Battle Experiments, the Joint National Training Capability (JNTC), and the Distributed Continuous Experimentation Environment (DCEE). In the future, simulation to C4ISR interoperability will be even more important as simulation capabilities are leveraged for embedded training and for critical Battle Command functions including mission planning, course of action analysis, and mission rehearsal. This will

demand an even greater level of simulation to C4ISR integration and will require the interoperation of simulations with C4ISR systems in an operational context, as well as for testing, training, and experimentation.

The increasing reliance on M&S to support battle command functions in all contexts is occurring at the same time that Department of Defense (DoD) concepts for warfighting, command and control, and the computing infrastructure that supports all information exchange are undergoing significant transformation. The DoD is moving from an Industrial Age, "platform-centric" force to an Information Age, "net-centric" force utilizing the principles of Net-Centric Operations and Warfare. Future Forces will rely heavily on the efficient collection, dissemination, analysis, and presentation of information to achieve Information Superiority, Decision Superiority, and Full Spectrum Dominance. They must act quickly and decisively against adversaries that are increasingly adaptive and asymmetric, and they must train and fight as part of a Joint, Interagency, Intergovernmental, and Multinational (JIIM) team. [7][6] The computing infrastructure that will enable this transformation is the Global Information Grid (GIG) [36], and the vision for how the GIG will operate is embodied in the DoD Net-Centric Strategies on Data, Enterprise Services, and Information Assurance as described in the Net-Centric Operations and Warfare Reference Model [22].

Very similar ideas are currently discussed within NATO concerning Net-enabled Capabilities. Although there are some differences in interpretation, the principles of Net-Centric Operations and Warfare discussed in this paper are applicable in this international context as well.

The interoperability of C4ISR systems and M&S is vital to this transformation because of the important role that M&S has in future operational battle command, as well as for testing, training, and experimentation. Since both C4ISR and M&S systems will reside on the GIG, the implication is that C4ISR and M&S systems must redefine how to interoperate according to the DoD Net-Centric Strategies using GIG Enterprise Services. While it may seem daunting to redefine the basic rules and methods of interoperation, the information transformation mandated by Net-Centric Operations and Warfare and enabled by the GIG may relieve many of the M&S to C4ISR interoperability difficulties that have persisted in the past. Net-Centric Operations and Warfare is *about* interoperability, and interoperability is now a requirement of information system design, not an afterthought.

How M&S and C4ISR systems may interoperate in the GIG environment is the subject of this paper. In Section 2 we describe the past, present, and future of simulation to

C4ISR interoperability to show the progress that has been made and the potential challenges of the future. In Section 3 we discuss future warfighting concepts, future Joint Command and Control, and the role of M&S. This is followed by Section 4, which is a description of the future information environment defined by the GIG, the DoD Net-Centric Data Strategy, and GIG Enterprise Services. Section 5 relates the information from the previous sections to postulate how to combine M&S and Joint Command and Control in the future information environment. Specifically, we look at how M&S supports Course of Action Analysis and how to incorporate elements of the Net-Centric Operations and Warfare Reference Model with ideas from Extensible Modeling and Simulation Framework (XMSF) research to create XMSF-like profiles for Joint Command and Control on the GIG. We conclude by reviewing the main ideas of the paper in Section 6, including limitations, suggestions for further research, and the possible role of SISO.

2 The Evolution of Simulation-to-C4I Interoperability

Approaches to achieving interoperability have improved significantly in recent years. This is due to many factors, including experience, progress in simulation-to-simulation interoperability, progress in C4I-to-C4I interoperability, the explosion of network-related technologies and standards driven by the Internet, and the increasing importance of M&S to C4I functions. The paradigm shift driven by Net-Centric Operations and Warfare, the DoD Net-Centric Strategies, and the GIG will improve simulation to C4I interoperability even further, perhaps in a revolutionary way. We are currently participating in a paradigm shift from project driven developments to portfolio driven procurements, or from system centric to service driven optimization. This paradigm shift will require a change of the escorting management processes as well, which is reflected in the research work described here.

2.1 Simulation-to-C4I Interoperability Past

In the past, simulation-to-C4I interoperability was mainly characterized by unique, often proprietary, and not reusable system-to-system interfaces handling only a subset of the message and data traffic and thus requiring significant human intervention to achieve the desired level of interaction. The requirement to interoperate was generally not known or disregarded during system design, and interoperability was an add-on capability that required engineers to force disparate systems to interact after they were fielded. Overarching standards to facilitate interoperability for M&S and/or C4I systems generally did not exist, or at best, each community or sub-community had its own unique standards that were not

compatible. Although there were some successes (e.g. simulations using tactical message formats to stimulate C4I systems), achieving interoperability was a painstaking, manual, and expensive process that had to be repeated for each pair of systems requiring interaction. Software updates on either system could wreak havoc with the existing, tenuous interface and necessitated that each interface be re-developed, re-configured, and/or re-tested. Simulation to C4I interfaces were primarily for testing or training, and there were few requirements for interoperability in an operational context, e.g. to facilitate planning, course of action analysis, or mission rehearsal. A study group conducted under the umbrella of SISO summarizes the same results in its reports [31][13].

This situation was recognized by the Army and led the Army Model and Simulation Executive Council to form the Simulation to C4I Interoperability (SIMCI) Overarching Integrated Product Team (OIPT) in 1999. [16] The SIMCI OIPT includes membership from both the M&S and C4ISR community and was chartered to develop solutions for Army M&S to C4I interoperability. The SIMCI "House Chart", Figure 2.1, shows that improving the interoperability of M&S and C4I systems requires shared solutions for both communities, including common standards, common data models, reusable interfaces, alignment of architectures, and alignment of processes. Although SIMCI OIPT is an Army organization, the concepts of the house chart apply throughout the DoD.

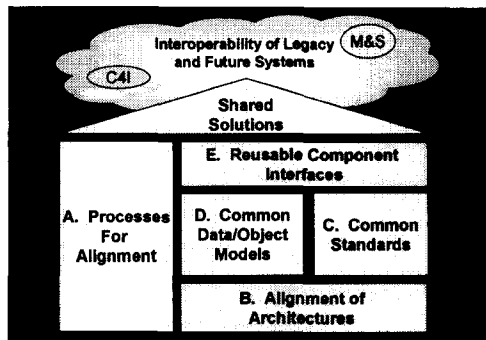


Figure 2.1 SIMCI "House Chart"

2.2 Simulation-to-C4I Interoperability Present

The current state of simulation to C4I interoperability is characterized by recognition of the importance of simulation to C4I interoperability when documenting required capabilities, and by increased emphasis on common data models, common standards, and alignment of architectures. In the Army, the emerging OneSAF and WARSIM constructive simulation systems have documented C4I interoperability requirements. Likewise,

the Future Combat System and Joint Command and Control - Army have documented M&S interoperability requirements. Interoperability standards development is proceeding within both the M&S and C4I communities individually, and more recently on standards that can be applied to both communities. For example, the M&S community developed the High Level Architecture (HLA) [18] and the Synthetic Environment Data Representation and Interchange Standard (SEDRIS) [30], while the C4I community developed the Command and Control Information Exchange Data Model (C2IEDM), used by 29 members of the Multinational Interoperability Program (MIP). [20] While these standards each originated within either the M&S or C4I community, there is recent interest in adapting these standards for use by both communities. Specifically, the M&S community is becoming increasingly interested in using C2IEDM¹, while the Army Future Combat System may adopt the Environmental Data Coding Specification (EDCS) of SEDRIS. Ongoing work recently presented to SISO tries to incorporate EDCS into C2IEDM [12]. Other emerging cross-community standards include the Battle Management Language (BML) [4], which standardizes and automates Operational Plans and Orders and other command and control documents for use in both M&S and C2 systems, and the Extensible Markup Language (XML), used by both C4I and M&S systems to facilitate data exchange [38]. In addition, both M&S and C4I systems must be documented according to the DoD Architectural Framework (DoDAF) [8], which is mandated for use by all developmental systems. Use of the DoDAF facilitates interoperability between Families of Systems (FoS) and Systems of Systems (SoS) by documenting each system's relationships to the other systems, including complex information exchange requirements. These types of standards improve interoperability for M&S and C4I systems within their own domains, as well as between M&S and C4I systems. There has also been a great deal of promising work in M&S in areas such as the Simulation Reference Markup Language (SRML) [29], Base Object Models [14], model-driven architectures [33], and in using web technologies to facilitate M&S interoperability through the Extensible Modeling and Simulation Framework (XMSF) concept [3][28]. These efforts will ultimately improve the level of M&S interoperability as well as M&S to C4I interoperability.

¹ The Army's SIMCI OIPT will be recommending the use of C2IEDM for M&S systems at the next meeting of the AMSEC. Furthermore, the NATO Modeling & Simulation Group (MSG) recommended the use of C2IEDM as a common information exchange reference model for C3I and M&S in the technical evaluation of their Conference on "C3I and M&S Interoperability," conducted in October 2003. [21]

Because of the progress that has been made in the M&S and C4I communities and in commercial networking technologies, the DoD now routinely conducts very large-scale simulation-to-C4I events such as JNTC training exercises and mission rehearsal exercises for deploying units. In addition, emerging simulations and C4I systems have “built-in” interoperability requirements that will reduce the need to create interfaces after a system has already been fielded. This success will further push the development of simulation-to-C4I capabilities and standards and has created a greater interest in and awareness of M&S capabilities to support battle command functions such as Course of Action Analysis.

2.3 Simulation-to-C4I Interoperability Future

As shown in Figure 2.2 and described in the remaining sections of this paper, Joint Vision 2020 and the capabilities required for Joint Command and Control will drive the future of simulation to C4I interoperability. These capabilities will be realized through the GIG according to the DoD Net-Centric Strategies. Joint Command and Control of the future will require quick access to timely, relevant data and will require vertical and horizontal interoperability to achieve Information Superiority and Decision Superiority. Joint Command and Control will leverage more M&S capabilities than ever before, and M&S will be an integral part of operational capabilities. In order to achieve M&S to C4I interoperability in this new environment, system designers will need to leverage previous work in M&S to C4I interoperability, M&S composability, web-based M&S, and commercial/private sector initiatives such as those of the World Wide Web Consortium (W3C) [39]. The M&S and C4I communities are at the threshold of a great opportunity to truly achieve a revolution in M&S to C4I interoperability.

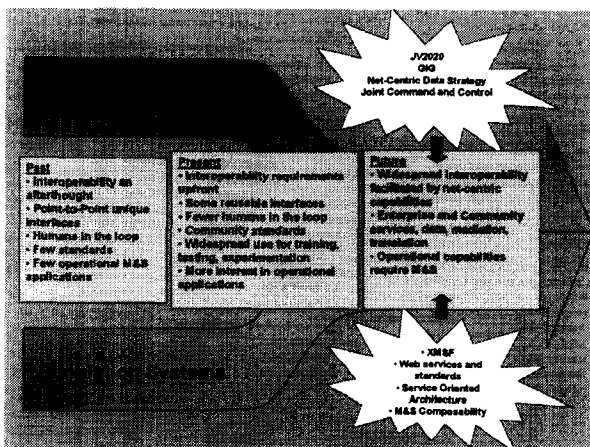


Figure 2.2 Sim to C4I Interoperability Future

3 Future Warfighting

The future of simulation to C4I interoperability is predicated on the future of Joint Command and Control and the technologies supporting it. This is best understood in the context of the future of joint warfighting, as outlined in Joint Vision 2010 (JV 2010) [6] and Joint Vision 2020 (JV 2020) [7].

3.1 Joint Vision 2010

JV 2010 describes itself as “the conceptual template for how we will channel the vitality of our people and leverage technological opportunities to achieve new levels of effectiveness in joint warfighting”. Key concepts discussed in JV 2010 are Information Superiority, Full Spectrum Dominance, and the operational concepts of Dominant Maneuver, Full Dimensional Protection, Precision Engagement, and Focused Logistics. Information Superiority is defined as “the capability to collect, process, and disseminate an uninterrupted flow of information while exploiting or denying an adversary’s ability to do the same”. JV 2010 holds that Information Superiority, enabled by technological innovation, will allow our forces to achieve Full Spectrum Dominance – “The ability of US forces, operating unilaterally or in combination with multinational and interagency partners, to defeat any adversary and control any situation across the full range of military operations”. The overall picture painted by JV 2010 is that of a very agile, lethal, and precise force enabled by information technology to be effective in all missions.

3.2 Joint Vision 2020

JV 2020 builds upon JV 2010, stressing the need for Joint, Interagency, Intergovernmental, and Multinational interoperability and calling for intellectual innovation as well as technical innovation. Two new areas of emphasis in JV 2020 are Information Operations and Joint Command and Control. The important concept of Decision Superiority – “better decisions arrived at and implemented faster than an opponent can react, or in a non-combat situation, at a tempo that allows the force to shape the situation or react to changes and accomplish its mission” – is also introduced, and the need for a global information environment is discussed. The concept for how the elements of JV 2010 and JV 2020 will achieve full spectrum dominance through interoperability is shown in Figure 3.1².

² This figure is extracted from the JV 2020 baseline briefing, at <http://www.dtic.mil/jointvision/baseline.htm>

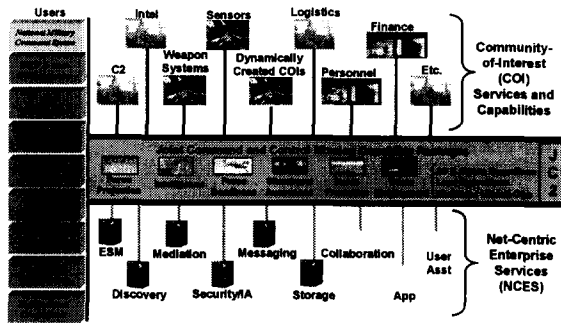


Figure 3.2 JC2 OV-1

3.4 Role of M&S

The role of M&S in supporting future Joint Command and Control is large and critical. M&S is prominent in the initial Capability Discussion section, which states that JC2 will "Provide Modeling and Simulation Systems". More references to M&S are found throughout the document, supporting a multitude of functions in all 9 MCP's. In addition, there are several references to "analysis" that would seem to implicitly call for modeling and/or simulation capabilities. Capabilities explicitly calling for M&S include:

- Training (to include embedded training, distributed training, self-development training, and Live-Virtual-Constructive simulations)
- Course of Action Analysis
- Mission Rehearsal
- En-route Mission Planning and Rehearsal
- Crisis Action/Adaptive Campaign Planning (to include Readiness Oversight, Total Force Analysis, Historical Trend Analysis, and Time-Phased Force and Deployment Data analysis)
- ISR management
- Joint Intelligence Preparation of the Battlefield
- Analysis of communication infrastructures, systems, and nodes

The prevalence of M&S in the JC2 CDD indicates that the relationship of M&S to command and control is changing. No longer is M&S "external" to command and control, e.g., as a stimulator for testing and training or as a standalone capability used for planning separate from the core command and control information systems. M&S is now a recognized function of Joint Command and Control that will be integrated with other JC2 capabilities to achieve Information Superiority, Decision Superiority, and Full Spectrum Dominance.

4 Future Information Environment

The future information environment is the net-centric environment within which all information-based systems including JC2 will operate, communicate, and store and share data. The future information environment is the Global Information Grid, and the key concepts driving the structure and operation of the GIG are the DoD Net-Centric Strategies. Important GIG capabilities include Enterprise Services and Communities of Interest Services. Information on how legacy and emerging applications may become "Net-Ready" is documented in the Net-Centric Operations and Warfare Reference Manual and the Net-Centric Checklist. Each of these items is discussed below.

4.1 The Global Information Grid

The Capstone Requirements Document for the GIG [36] defines it as a "globally interconnected, end-to-end set of information capabilities, associated processes, and personnel for collecting, processing, storing, disseminating, and managing information on demand to warfighters, policy makers, and support personnel". This includes all owned and leased communications and computing systems and services, software, data, security services, and other associated services. Any DoD system, equipment, software, or service that meets one or more of the following criteria is considered part of the GIG:

- Transmits information to, receives information from, routes information among, or interchanges information among other equipment, software, and services.
- Provides retention, organization, visualization, information assurance, or disposition of data, information, and/or knowledge received from or transmitted to other equipment, software, and services.
- Processes data or information for use by other equipment, software, and services.

The basic operational concept of the GIG is that warfighters and other authorized users in the DoD and Intelligence Community or beyond can "plug into" the GIG and satisfy their information requirements any time, anywhere, much like the private sector uses the Internet. The vision is to facilitate interoperability among the elements of the existing IT infrastructure, integrating disparate systems and networks into a global system of systems. Figure 4.1 is the High Level Operational View of the GIG from the GIG CRD.

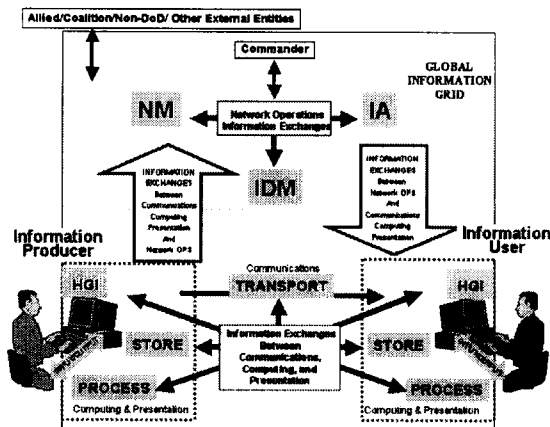


Figure 4.1 GIG OV-1

The GIG will employ a Service-Oriented Architecture (SOA) as depicted in the JC2 OV-1, Figure 3.2. A SOA is a collection of well-defined, self-contained, independent functions (services) that can be discovered and invoked in various combinations to achieve an objective. This is a flexible approach that facilitates reuse of common capabilities and supports unanticipated uses/users. Use of an SOA for the GIG is significant because of its flexibility and because it parallels what is being done in the commercial sector, allowing the DoD to leverage advances in commercial technologies such as web services.

There are fundamentally two different types of GIG Enterprise Services: Core Enterprise Services (CES), and Community of Interest (COI) services/capabilities. CES are basic, common computing services that are available across the enterprise to users and/or applications residing on the GIG. COI services/capabilities are more complex software applications that are generally of interest within a specific functional community, as opposed to the entire enterprise. There are presently nine CES identified for development and use on the GIG. COI Services will be identified and developed by their respective COIs and could number in the thousands. CES and COI Prototype Services are described in more detail in sections 4.3 and 4.4.

4.2 DoD Net-Centric Data Strategy

The core of the net-centric environment is the data that enables information superiority, and ultimately decision superiority. The DoD vision for a net-centric environment and the data goals for achieving it are described in the Net-Centric Data Strategy [9]. This is an important document that describes many of the key concepts driving the architecture, capabilities, and management structure of the GIG. The Net-Centric Data

Strategy, together with the Net-Centric Enterprise Services Strategy and the Net-Centric Information Assurance strategy form an integrated approach to achieving net-centricity.

The Net-Centric Data Strategy advocates a different approach to data management and interoperability than the traditional DoD approach. Rather than focusing on rigid data standardization, central data administration, and tightly engineered, point-to-point interfaces, the new DoD data vision is more flexible and emphasizes data visibility and data access. It recognizes that data standardization and administration on an enterprise-wide scale is virtually impossible for the DoD. Furthermore, net-centricity requires many-to-many interfaces, and unanticipated requirements for data sharing and interoperability are constantly emerging. While tightly engineered interfaces and standardization of data between specific systems will still exist for some applications, data will become increasingly visible and accessible within user communities and across the enterprise. This will enable users and applications to become aware of and use existing data more readily, as shown in Figure 4.2³.

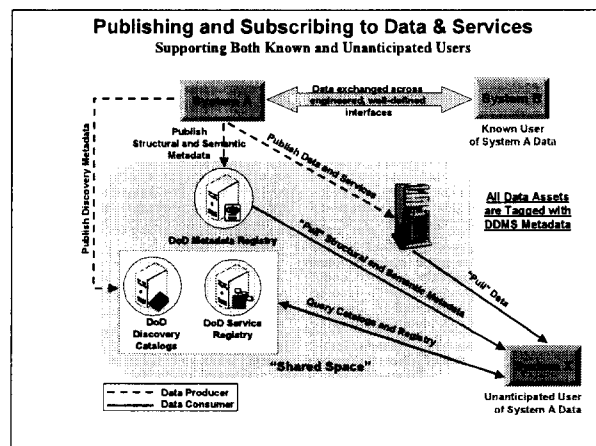


Figure 4.2 Net-Centric Data Strategy Concept

The Net-Centric Data Strategy describes seven data goals for achieving the DoD Data Vision:

1. Make Data Visible
2. Make Data Accessible
3. Institutionalize Data Management
4. Enable Data to be Understandable
5. Enable Data to be Trusted
6. Support Data Interoperability
7. Be Responsive to User Needs

³ This figure is extracted from a briefing by Mike Krieger, OSD(NII), given to the M&S COI on 16 Nov, 2004.

The first 3 goals seek to reduce the amount of private data and make it available within a wider community or across the enterprise. The remaining 4 goals seek to increase the use of data within a community or the enterprise. Key to achieving these data goals are Metadata, Communities of Interest, and the GIG Enterprise Services.

Metadata is the key to making data visible, accessible, and understandable. Information about what information is available, how to access it, and what it means must be “published” by data producers according to the DoD Discovery Metadata Specification (DDMS). [10] This allows data consumers within a COI or across the enterprise to “discover” and use data within their own applications. Metadata registries, metadata catalogs, and shared spaces (virtual or physical) for publishing common data and metadata are all important elements of achieving net-centricity.

The idea of DoD specific metadata was only recently replaced by a more general concept. DDMS is now integrated in the National Security Information Standards for Resource Metadata as the Application Profile for Discovery (APD). The driving force behind this merging is the need for interagency interoperability for homeland security enabling collaborations.

Communities of Interest (COI) are “collaborative groups of users who must exchange information in pursuit of their shared goals, interests, missions, or business processes and who therefore must have shared vocabulary for the information they exchange”. There are two basic types of COIs: institutional and expedient. Institutional COIs are longer-term, formal organizations with a continuing role in managing the data needs of a community. Expedient COIs are tactically-driven groups of users who come together for a short time to solve a specific problem. In the near term, institutional COIs (e.g., the M&S COI led by the Defense Modeling and Simulation Office) will provide a mechanism for achieving the goals of the net-centric data strategy within a particular functional area or community. They decide which data should be published within the community or to the enterprise, develop metadata standards for metadata registries and catalogs, and encourage members of the community to participate by publishing data and/or by using published data to achieve required capabilities.

GIG Enterprise Services are also critical to implementing the Net-Centric Data Strategy on the GIG because they provide the means for data discovery, storage, access, translation, transmission, etc. This includes both CES (e.g. discovery, storage, and mediation) and COI services. An important GIG Enterprise Service is the DoD Metadata Registry, a “one-stop shop for developer data

needs”. Expected contents of the DoD Metadata Registry are shown in Figure 4.3⁴.

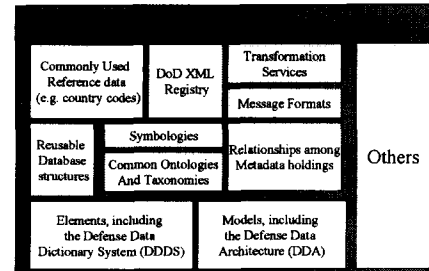


Figure 4.3 DoD Metadata Registry

4.3 GIG Core Enterprise Services (CES)

The DISA Net-Centric Enterprise Services (NCES) Program is charged with developing the GIG CES. As described in the previous section, CES are common computing services that are available across the enterprise for use by GIG users and/or GIG applications. CES will provide the means for data producers to publish data and metadata and for data consumers to discover and access it. Reliable identification and authorization services are required, as are data mediation services to resolve differences in name, structure and representation of data. There are currently 9 categories of CES identified for development as part of the NCES program. They are defined as [32]:

- **Enterprise System Management (ESM) Services:** The set of services that enable the life-cycle management of the information environment and support the performance of the NetOps activities necessary to operationally manage information flows in the information environment.
- **Messaging Services:** Provides services to support synchronous and asynchronous information exchange.
- **Discovery Services:** The set of services that enable the formulation and execution of search activities to locate data assets (e.g., files, databases, services, directories, web pages, streams) by exploiting metadata descriptions stored in and or generated by IT repositories (e.g., directories, registries, catalogs, repositories, other shared storage).
- **Mediation Services:** The set of services that enable transformation processing (translation, aggregation,

⁴ This figure is adapted from Figure 6 in the Net-Centric Data Strategy.

- integration), situational awareness support (correlation and fusion), negotiation (brokering, trading, and auctioning services) and publishing.
- **Collaboration Services:** The set of services that allows users to work together and jointly use selected capabilities on the network (i.e., chat, online meetings, work group software etc.)
 - **User Assistance Services:** Automated capabilities that learn and apply user preferences and patterns to assist users to efficiently and effectively utilize GIG resources in the performance of tasks.
 - **Information Assurance/Security Services:** The set of services that provide a layer of Defense in Depth to enable the protection, defense, integrity, and continuity of the information environment and the information it stores, processes, maintains, uses, shares, disseminates, disposes, displays, or transmits.
 - **Storage Services:** The set of services necessary to provide on demand posting, storage and retrieval of data.
 - **Application Services:** The set of services necessary to provision, host, operate and manage the GIG ES assured computing environment.

The basic functions performed by the CES are the reusable building blocks for creating more complex COI Services. By providing reusable capabilities, the CES reduce the time, cost, and risk of developing, maintaining, and supporting COI services. This ultimately leads to more flexible and "lightweight" capabilities, better able to adapt to changing information needs.

4.4 GIG COI Prototype Services

COI services are more complex software applications that are generally of interest within a specific functional community, as opposed to the entire enterprise. COI Services are developed by either expedient or institutional COIs for use within their community. In addition, the DISA NCES program is also assisting with the development of some prototype COI Services as a way of fleshing out the operating concepts of the GIG and refining the requirements for the CES.

Two emerging GIG COI prototype services of interest are Blue Force Tracking (BFT) and Global Force Management (GFM). The BFT COI Service was developed by Mitre to "demonstrate the Net-Centric Data Strategy in action". [27] The objective was to provide a net-centric Blue Force Situational Awareness and Blue Force Tracking service, despite incompatibilities between the various Blue Force Tracking systems used by the Services. The solution uses web services technology and GIG CES to allow 5 different BFT systems (using both satellite and radio-based communications and a variety of message formats) to publish their data. This data was

then available to a virtually unlimited number of subscribers to consume it, as shown in Figure 4.4. The sequence for posting and receiving data is as follows:

1. Provider(s) (e.g. Army FBCB2) locate BFT Service.
2. Provider(s) register with BFT Service.
3. Consumer(s) (e.g. Air Operations Center) locate BFT Service.
4. Consumer(s) subscribe to BFT Service.
5. Provider(s) post BFT info to BFT Service.
6. BFT Service delivers info to every subscribed consumer, including unanticipated users.

A demonstrated application of this BFT service was for Time-Sensitive Targeting, whereby the Air Operations Center (AOC) becomes aware of a potential target and must act quickly before the opportunity is lost. By providing Blue Force Situational Awareness/Blue Force Tracking information for all components in a timely manner, the BFT service maximizes the opportunity for destroying the target while minimizing the opportunity for fratricide.

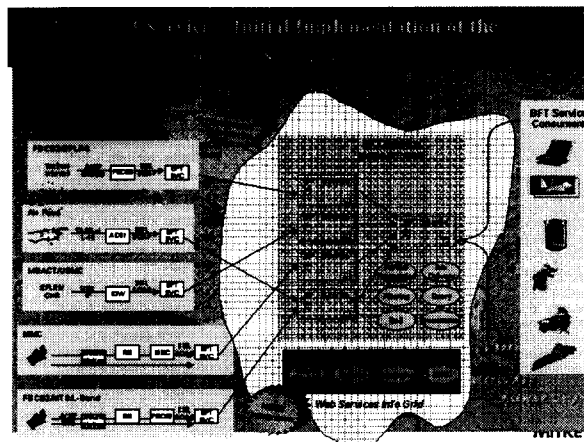


Figure 4.4 Blue Force Tracking on the GIG

In a similar manner, The Joint Staff J8 developed a Global Force Management (GFM) COI Service to demonstrate the application of Net-Centric Data Strategy concepts and CES to maintain awareness of the force structure, resources, capabilities, and readiness levels of DoD forces throughout the world. [2] This is critical information that is required for a number of applications in the Business and Warfighter Domains, such as readiness reporting, campaign planning, budgeting, and for initializing simulations and C4I systems. The GFM Service pulls together data in a variety of different formats from a variety of authoritative data sources and makes it "discoverable" and accessible to authorized users across the enterprise. It should be noted that both prototypes utilize information models based on the

C2IEDM, implementing extensions to meet their specific requirements.

4.5 Becoming "Net-Ready"

The previous sections described various concepts of the GIG, the Net-Centric Data Strategy, Core Enterprise Services, and two prototype emerging COI Services. Legacy or emerging systems that wish to be "net-ready" may refer to two key documents: the Net-Centric Operations and Warfare Reference Manual [22], and the Net-Centric Checklist [23].

Net-Centric Operations and Warfare Reference Model (NCOW-RM). The NCOW-RM is a comprehensive, authoritative reference describing the essential objects, relationships, and processes that comprise net-centric operations and warfare. It provides for a shared understanding of net-centricity and supports decision makers, capability developers, and program managers in their efforts to transform. NCOW-RM Version 1.0 was published in December 2003. A draft NCOW-RM Version 1.1 which refines and extends the information in the initial version was published in November 2004. Additional versions will be published as more information becomes available through the NCES Program, COI Service Prototypes, etc.

Key elements of NCOW-RM Version 1.1 are descriptions of the relevant DoD Net-Centric Strategies (Data, Enterprise Services, and Information Assurance), the GIG target information environment, Reference Model components, and guidance on how to use the Reference Model. Reference Model components consist of an Operational Description, System/Services Description, the Target Technical View, and an Integrated Dictionary. Primitive use cases, key policy requirements, and a recommended reading list are also included in the document.

Net-Centric Checklist. The Net-Centric Checklist is an extract of the NCOW-RM intended to assist program managers (PM) in understanding the requirements of net-centricity. It is intended as a tool for self-assessment, unlike the NCOW-RM Compliance Assessment Methodology, which is a formal assessment of whether a program complies with the NCOW-RM. The checklist is divided into four sections: Data, Services, Information Assurance/Security, and Transport. Each section consists of a series of questions to assist the PM in assessing how well his/her program is aligned with the design tenets and standards of the GIG. For example, a question in the Data section reads:

Does the program provide discovery metadata in accordance with the DoD Discovery Metadata Standard for all data posted to shared spaces?

Similarly, a question in the Service section reads:

Are web services implemented by the program built using the following core standards? (This question is followed by a list of current and emerging web standards.)

In general, the questions in the Net-Centric Checklist are centered on describing how the program is net-centric, how it is aligned with the NCOW-RM, how it utilizes IT/NSS standards from the DoD Joint Technical Architecture, and whether it has created the required DoD Architecture framework products.

5 JC2 and M&S in the Future Information Environment

The previous sections described future warfighting concepts and the future information environment that will support it. This section will describe how M&S and JC2 will operate in this environment, and how they will interoperate using Course of Action Analysis as a Use Case. An XMSF-like profile for JC2/M&S Integration is offered.

5.1 M&S in the Future Information Environment

There are two fundamental perspectives from which to view M&S in relation to the future information environment of the GIG:

- M&S of the GIG: Modeling and simulation of the GIG infrastructure and operation, e.g. to determine the optimal network configuration, determine bandwidth requirements, identify bottlenecks, etc.
- M&S on the GIG: M&S that resides and operates on the GIG, such as for training, operations, acquisition, analysis, etc. Virtually all M&S of the future will reside on the GIG.

While M&S of the GIG (i.e. network modeling) is an extremely important topic for net-centric operations and warfare, this paper is concerned with how M&S will operate on the GIG because this is where M&S will interoperate with JC2.

Regardless of the M&S application, M&S of the future will have to change in some manner to comply with the requirements described in the NCOW-RM. Almost no M&S application is "safe" by the definition of the GIG. However, the degree of change will be determined by the willingness of the M&S community to embrace the

concepts of net-centricity and rethink how we implement distributed M&S.

The minimal change required for M&S to reside on the GIG is to:

- Package current M&S applications into application-sized services that can be discovered and invoked.
- Publish only final results of operations, hiding intermediate results and internal data and models.
- Use a minimal, static set of CES and COI Services to create a fixed set of capabilities.
- Maintain the current concepts of interoperability as defined by HLA with minimal changes to use web services and standards dictated by the NCOV-RM.

This solution requires less work and does not require a paradigm shift in M&S thinking. It is the most familiar solution. However, the minimal solution does not take advantage on the future information environment, does not advance the state of the art appreciably, and will not in itself allow for any new capabilities.

In contrast, a truly net-centric M&S approach to the GIG will require the following changes:

- Component-sized M&S services that can be configured and re-configured into the required capabilities on the fly. (See [25][14][29])
- Publication of intermediate and internal data for possible use by other services and users.
- Maximal use of COI Services and CES to create flexible, dynamic capabilities.
- Rethinking HLA in terms of a Service Oriented Architecture.

This solution requires more work and represents an M&S paradigm shift both psychologically and technically. However, it is a much more flexible and adaptive solution that allows for integrated M&S capabilities vice interoperable M&S. The result is truly net-centric M&S.

5.2 JC2 in the Future Information Environment

The command and control community is faced with the same challenges as the M&S community in terms of how to take full advantage of the future information environment. However, because the current and future operating environment demands it, the command and control community recognizes that they must implement a solution that allows for a flexible and adaptive capability that can readily change as the situation demands.

The current thinking on how to implement JC2 on the GIG is represented in the evolving JC2 DoDAF products and the NCOV-RM. A glimpse of this thinking was presented by DISA at a recent NCES Industry Day [11] and is shown in Figures 5.1 and 5.2.

Figure 5.1 shows a generic depiction of the GIG as a Service Oriented Architecture (SOA), with the network layer as a foundation. The top layer consists of applications and application building blocks known as COI Services, which make use of lower-level Core Enterprise Services.

Figure 5.2 depicts how the JC2 users and Mission Capability Packages (MCP) ride on this architecture. JC2 users represent the top layer of the JC2 architecture. They use applications within the MCPs to accomplish a multitude of functions defined by mission threads. MCPs are comprised of several COI Services that make use of Core Enterprise Services (CES) and possibly other COI services. An additional layer, called C2 services, is also shown. This represents common services used by the JC2 COI or JC2 COI Services, but that are not of interest enterprise-wide as are the CES. This is an interesting concept for M&S community as well whereby basic M&S building blocks could be defined to facilitate the construction of more complex M&S COI Services.

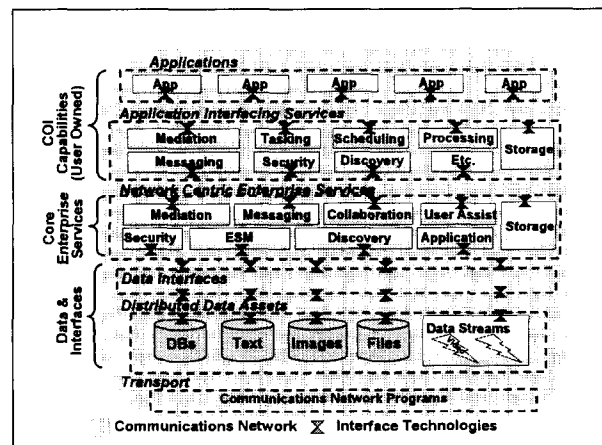


Figure 5.1 GIG Service Oriented Architecture

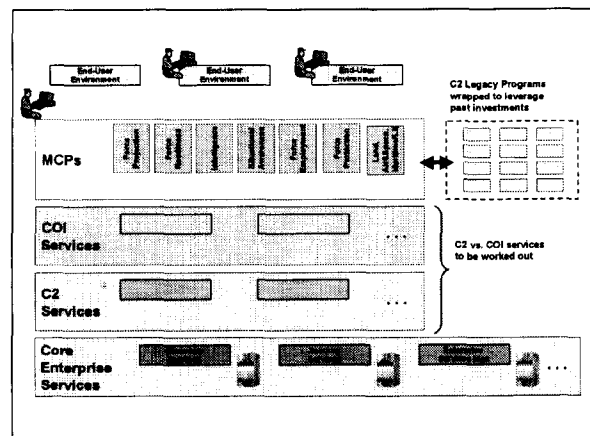


Figure 5.2 JC2 in a Service Oriented Architecture

5.3 M&S and JC2 Interoperability Use Case

If the M&S community fully embraces the net-centric concept, M&S and JC2 interoperability in the future information environment can truly be revolutionary. To illustrate this, we will employ Course of Action Analysis (COAA) as our use case, a concept that many readers will be familiar with.

COAA is part of the Force Employment MCP of JC2 within the function Adaptive Campaign Planning. Referring to Army FM 5-0 [15], COAA is employed in the Military Decision Making Process (MDMP) to evaluate one or more approaches to accomplishing a given mission. COAA, also known as Wargaming, is a collaborative process whereby the battlestaff engages in a detailed analysis of how well a given approach accomplishes a mission, what the resource requirements are, how various aspects of the battle plan must be synchronized, etc. While COAA can be (and most often is) done manually using hard copy maps, acetate overlays, calculators, laptops, etc., the COAA process can be greatly enhanced by M&S. Using M&S tools such as a terrain visualization capability or a constructive simulation, a battlestaff can more readily visualize the battlespace, determine required interactions, run through multiple variations of a given COA, replay particularly difficult aspects, etc. In addition, M&S software can assist with populating the synchronization matrix and staff estimates as elements of the plan are changed, a normally very tedious and time-consuming process. Use of M&S tools allow the commander and staff to analyze a COA more quickly, more thoroughly, and more accurately, leading to a more adaptive, agile force.

5.4 COAA on the GIG.

A practical example of how M&S can be integrated with C2 systems to support COAA is the work that has been done in BML [4], XBML [17], and XBML integrating ground and air operations [24]. While the focus of this work is on BML as a mechanism for creating and communicating plans and orders between C2 and simulation systems, the resulting configuration is one that could support COAA in the manner described in the previous section because it integrates C2 systems with M&S tools. In the original BML work and in XBML, the Army C2 system CAPES was integrated with the Army simulation OneSAF. In the integrated ground/air XBML work, the Air Force C2 system TBMCS and CAPES were linked with the joint simulation JSAF as shown in figure 5.3.

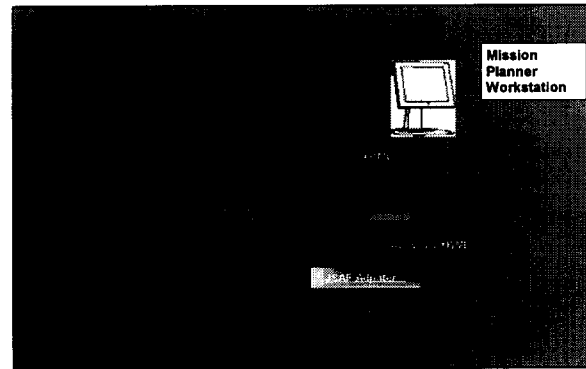


Figure 5.3 Air/Ground XBML System Configuration

Integrated air/ground XBML, an XMSF exemplar, is of particular interest because it employs a Service Oriented Architecture and uses many of the same web services that are identified in the NCOW-RM, including XML, WSDL, SOAP, XSD, and XSLT. However, while this work is groundbreaking in terms of simulation to C4I interoperability, the result is not a true GIG-compliant solution to integrating M&S with C2 systems. This is primarily because it does not adhere to the publish and subscribe paradigm of the Net-Centric Data Strategy. It also does not use GIG CES or any other COI services, although it must be noted that these capabilities are only now emerging.

An ideal implementation of COAA on the GIG for JC2 would incorporate CES such as collaboration, messaging, and discovery and COI Services such as Global Force Management for Unit Order of Battle data, the Joint Geospatial Enterprise Service⁵ for terrain data, and the Blue Force Tracking Service for determining the location of friendly forces. M&S capabilities would be implemented as COI services and/or core M&S services, and the COAA Service would dynamically configure required services and data to suit the mission using publish and subscribe mechanisms. This configuration is depicted in Figure 5.4. Referring back to Figure 5.2, this can also be depicted as a layered architecture, with M&S Services, C2 Services, and data services such as JGES, GFM and BFT all included in the COI Services layer. Generic C2 and/or M&S services such as visualization and simulation time synchronization may be included in a layer below the COI Services, indicating that these may be used as components of more complex COI services.

⁵ JGES is an emerging capability that was only recently approved by the Joint Requirements Oversight Council. Prototyping efforts are underway.

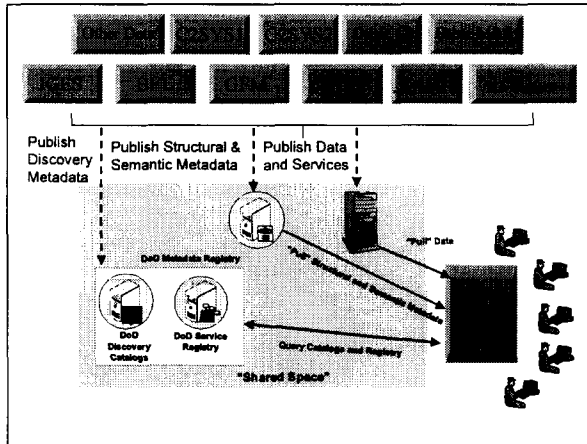


Figure 5.4 Net-Centric COAA

5.5 An XMSF-inspired Profile

XMSF is defined as a composable set of standards, profiles, and recommended practices for Web-based modeling and simulation [3]. The goal is to enable simulations to interact directly and scalably over a highly distributed network using web technologies and standards. A SISO XMSF Study group has been formed, and there are several papers describing XMSF concepts and XMSF exemplars that have successfully used web services and standards to implement distributed simulations. [1][28][19]

XMSF is important to the integration of M&S and JC2 on the GIG and to GIG implementations of M&S in general because the GIG and XMSF have the same goals, except that the GIG is concerned with information technology in general, not just M&S. The GIG and XMSF also share the same ideas regarding the exploitation of commercial networking technologies from the Internet. Specifically, the GIG will be implemented using Internet Protocol 6 and is using many of the same web services and standards that are advocated by XMSF. These include SOAP, UDDI, WSDL, XML, XSLT, etc.

The experience that the M&S community has with XMSF will greatly facilitate the migration of M&S to the GIG, which is essential to the warfighter. One mechanism for documenting the specifics of XMSF is the XMSF profile. While the actual format and structure of an XMSF profile is still fuzzy, the formal definition is as follows⁶: *XMSF profiles are formal technical specifications for the application of interoperable web-based technologies enabling composable and reusable modeling and simulation, and facilitating enterprise integration.* In [34], it is suggested that a modified web service stack

using the concept of platform independent models (PIM) would be a good basis for XMSF profiles. As shown in Figure 5.5, this is a layered architecture along the lines of the ISO/OSI model [26] and is also similar to Figures 5.1 and 5.2 above, representing the current thinking for the GIG and JC2. The inclusion of the PIM at each layer suggests that the specific implementation at each layer is independent of the required capability represented in the PIM. A given application could be realized using one or more of the mechanisms at each layer.

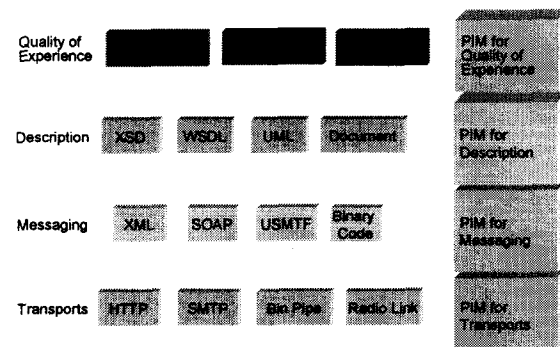


Figure 5.5 Modified Web Service Stack

The combination of the concepts in Figures 5.1, 5.2, and 5.5 suggests a profile for the integration of M&S with JC2 (or any function) in the GIG environment. This JC2/M&S Integration Profile is shown in Figure 5.6, including sample data from the COAA use case. The profile depicts the layers of the GIG from the physical infrastructure to the users. Keeping the GIG layered architecture of Figure 5.1 in mind, the bottom 4 layers are adopted from the ISO/OSI model, the next 4 layers are adopted from the modified web service stack and the extended web service stack⁷, and the top 5 layers, starting with CES, are from the JC2 layered architecture in Figure 5.2. The lower portion of the profile consists of Enterprise-Defined functions that are the responsibility of DISA and NII. The upper portion of the profile consists of User-Defined functions that "ride" on the enterprise-defined functions and are the responsibility of a given COI. Data and metadata are included as a pseudo-layer between the User-defined portion of the profile and the Enterprise-Defined portion because of its special importance in the overall net-centric concept. This represents the data, metadata, shared space, and registries/catalogs such as the DoD Metadata Registry, DoD Service Registry, and DoD Discovery Catalog.

⁶ From the XMSF Study Group reflector, 22 OCT 03

⁷ The service composition layer is not part of the modified web services stack, but it was part of the extended web service stack discussed in [34].

User-Defined	Profile Layer	JC2 COAA Use Case
	Users	JFC and Staff
		Force Projection (Adapt. Camp. Planning)
	Core COI Services	COAA: GFM, BFT, IGES, SAF, C2SYS 3DVis, Sim Synch, Data Collection, etc.
Enterprise-Defined	DATA & METADATA	
	Core Enterprise Services	(9) Collab., Messaging, Discovery, etc.
		WS-Service Group, BPEL4WS, etc.
	Quality of Experience	WS-Security, WS-transaction, etc.
		WSDL, XSD, UML, etc.
		XML, SOAP, etc.
	Network	HTTP/HTTPS, SMTP, etc.
	Data Link	LAN Drivers, SIP
	Physical Infrastructure	Media Access Control
		fiber, satellite, radio, plane-based, etc.

Figure 5.6 JC2/M&S Integration Profile

The definitions of most of the layers are self-evident from the previous discussion and from familiarity with the ISO/OSI network model and web services. The 4 layers immediately below the Core Enterprise Services will be very important mechanisms for implementing the CES described in section 4. Of special note is the inclusion of a "Core COI Services" layer. This is not a recognized type of service per current GIG documentation, which only recognizes the CES and COI Services. It is offered as a special type of COI Service that is characterized by its utility across the COI (and perhaps within other COIs) as a building block for more complex COI Services. This speaks to the common components and composability concepts of M&S. Depending on the degree of decomposition, examples in M&S might include a simulation data collection service, synchronization and timing functions, a simulation engine, behavioral models, and HLA RTIs.

The purpose of the profile is to illustrate how the GIG is logically structured and the issues that must be addressed for M&S interoperability on the GIG. For each M&S use case, one would populate the right side of the profile with specific information at each layer. The lower part of the profile below the CES will be defined by the Enterprise, with the CES providing the interface between the upper layers and these lower layers.

Because M&S is not an end in itself but a tool to be integrated into various applications and services of the GIG, it is important for the M&S community (through the M&S COI) to begin by identifying the users and uses of M&S on the GIG. This will help identify the required M&S services for each COI to support various users and applications within JC2 and for the DoD in general. Applied M&S cannot be a purpose on its own, but all application domains of M&S within the GIG must be supported. These application domains will be distributed over multiple COIs within the Warfighter, Business, and

Intelligence Domains to include Training, Sense Making, Testing, Acquisition, etc.

To implement the ideal "net-centric M&S" solution as discussed in section 5.1, the M&S COI must also identify and develop Core COI Services for M&S. These are the technical core solutions (e.g., items such as the HLA runtime infrastructure functionality) which be applied within all applicable COI to create more complex COI Services. Developing metadata and metadata standards for M&S services/data are also extremely important functions for the M&S COI. In general, the appropriate focus for most of the M&S community would appear to be in the metadata and in the user-defined arena of the profile because the lower portion of the profile will be Enterprise-defined. However, leaders of the M&S community must stay engaged with DISA and others to ensure that M&S unique characteristics are accounted for as decisions are made regarding the enterprise and the CES.

6 Summary and Conclusions

The goal of this paper was to describe how future warfighting concepts and the future information environment will impact the future of M&S to C4I interoperability, using JC2 as an example. We began with a short history of M&S to C4I interoperability and the challenges and opportunities of the future. We then discussed future warfighting concepts, future Joint Command and Control, and the role of M&S in the JC2 system. Next, we described the future information environment defined by the GIG, the DoD Net-Centric Data Strategy, and GIG Enterprise Services. Finally, in Section 5 we related the information from the previous sections to postulate how to combine M&S and Joint Command and Control in the future information environment. Specifically, we looked at how M&S will support Course of Action Analysis and how to incorporate M&S into current concepts for implementing JC2 on the GIG. The result is the JC2/M&S Integration Profile, shown in Figure 5.6.

6.1 Challenges for M&S Community

Although the concept of the future information environment defined by the GIG and the Net-Centric Data Strategy are very powerful, there are a number of challenges toward actually implementing it successfully within the M&S community (and in general). A few of the challenges are as follows:

- Overcoming the current mindset, which tends to be stove-piped capabilities and data that are not shared across the enterprise or even within the M&S community.

- Creating the required metadata to describe an M&S service or data in enough detail that an unintended user can discover it, understand what it means, and use it successfully.
- Redefining M&S capabilities as services or groups of services
- Identifying Core M&S COI Services to be used as M&S building blocks
- Identifying M&S Users and uses across the enterprise and ensuring that the required M&SA services are available
- Ensuring that the Enterprise capabilities provided by DISA support the unique requirements of M&SA

6.2 Role of SISO

SISO can and must play a large role in the transition of M&S to the GIG (and/or the web). Four potential contributions are:

- Developing the appropriate metadata standards and techniques for describing M&S services and data
- Developing guidance and standards for composability on the GIG, e.g. what are the Core M&S COI services?
- Aligning XMSF work with GIG implementation efforts to ensure that the unique requirements of the M&S community are recognized by DISA and NII.
- Rethinking HLA and other distributed simulation standards and techniques in terms of a Service Oriented Architecture

Furthermore, an active engagement of all services as well as of the joint organizations, in particular the Defense Modeling and Simulation Office and the Joint Forces Command, is mandatory for a user driven, successful aligned approach to the challenges sketched in this paper. A key role is seen in the establishment of a M&S Community of Interest based on the continuing dialogue of all parties, which include government (focusing on requirements and alignment of projects into portfolios), industry (communicating constraints and implementing the ideas), and academia (as an unbiased and competent idea-broker and vendor-neutral peer-reviewer).

6.3 Conclusions

Future warfighting concepts and the future information environment present a tremendous opportunity to revolutionize M&S to C4I interoperability and interoperability in general. Net-Centric Operations and Warfare is about interoperability, and the Net-Centric Data Strategy and the GIG provide the means to achieve it on an enterprise-wide scale. Because M&S has an important role in helping the future warfighter achieve information and decision superiority, it is critical that the M&S community embrace this opportunity.

6.4 Limitations

The ideas presented in this paper are based on JC2 and GIG implementation concepts that are constantly evolving. Due to the nature of emerging and agile projects such as the GIG, it is recommended that interested readers refer to the latest versions of the JC2 CDD, the NCOW-RM and other items on the DISA and NII websites for the latest information.

7 References

- [1] Blais, C., "Extensible Modeling and Simulation Exemplars in Analytic Combat Modeling", Paper 04S-SIW-142, Spring 2004 SIW, Washington, DC, April 2004.
- [2] Boller, M. (Joint Staff J8): "Global Force Management", briefing, DMSO M&S COI Kickoff, 16 Nov 2004.
- [3] Brutzman, D. et al: "Extensible Modeling and Simulation Framework (XMSF) Challenges for Web-based Modeling and Simulation", Findings and Recommendations Report from the XMSF Technical Challenges Workshop and Symposium, Monterey, CA, October 2002.
- [4] Carey, S. et al: "Standardizing Battle Management Language -A Vital Move Towards the Army Transformation", Paper 01F-SIW-067, 2001 Fall Simulation Interoperability Workshop, Orlando, FL, 2001.
- [5] Chairman of the Joint Chiefs of Staff, U.S. Department of Defense: "Joint Publication 1-02, DoD Dictionary of Military and Associated Terms", 12 April 2001 (as amended through 30 November 2004).
- [6] Chairman of the Joint Chiefs of Staff, U.S. Department of Defense: "Joint Vision 2010", Defense Technical Information Center, <http://www.dtic.mil/>.
- [7] Chairman of the Joint Chiefs of Staff, U.S. Department of Defense: "Joint Vision 2020", Defense Technical Information Center, <http://www.dtic.mil/>.
- [8] Department of Defense Architecture Framework Working Group, Office of the Assistance Secretary of Defense (Networks and Information Integration): DoD Architectural Framework Version 1.0, 9 Feb 2004.
- [9] Department of Defense Chief Information Office: Department of Defense Net-Centric Data Strategy, Net-Centric Data Strategy, May 2003.

- [10] Deputy Assistant Secretary of Defense (Deputy Chief Information Officer): "Department of Defense Discovery Metadata Specification Version 1.2", Jan 2005.
- [11] Diggs, Don (OASD(NII)), "A Strategic Approach for Interoperability", briefing included in M&S COI Kickoff meeting materials, 16 Nov 2004.
- [12] Dobey, V., Eirich, P.: "Environmental Data Models: Necessary but Not Sufficient for Interoperability", Paper 04S-SIW-114, 2004 Spring Interoperability Workshop, Arlington, VA, April, 2004.
- [13] Griffin, A., Lacetera, J., Tolk, A.: "C4ISR/Sim Technical Reference Model Study Group Final Report", Simulation Interoperability Workshop, Orlando, FL, September, 2002.
- [14] Gustavson, P. et al: "BOM Study Group Final Report", Spring Simulation Interoperability Workshop, March, 2001.
- [15] Headquarters, Department of the Army, "FM 5-0 Army Planning and Orders Production", January 2005.
- [16] Hieb, M. et al, "The SIMCI OIPT: A Systematic Approach to Solving M&S/C4I Interoperability", Paper 02F-SIW-067, 2002 Fall Simulation Interoperability Workshop, Orlando, FL, 2002.
- [17] Hieb, M. et al., "Developing Battle Management Language into a Web Service", 04S-SIW-113, 2004 Spring Simulation Interoperability Workshop, Crystal City, VA, 2004.
- [18] The Institute of Electrical and Electronics Engineers: IEEE Standard 1556 for Modeling and Simulation (M&S) High Level Architecture (HLA)--- Framework and Rules, <http://www.ieee.org>, 2000.
- [19] Morse, K., "Web Enabling an RTI - an XMSF Profile", Paper 03E-SIW-046, 2003 European SIW.
- [20] Multinational Interoperability Programme: Overview of the C2 Information Exchange Data Model, Greding Germany, 20 November 2003.
- [21] NATO Modeling and Simulation Group: "C3I and Modeling and Simulation (M&S) Interoperability", Summary of 9-10 Oct 2003 conference, Antalya Turkey, (Published March 2004).
- [22] Office of the Assistant Secretary of Defense for Networks and Information Integration: "Global Information Grid Net-Centric Operations and Warfare Reference Manual version 1.1 (draft)", 17 November 2004.
- [23] Office of the Assistant Secretary of Defense for Networks and Information Integration: "Net-Centric Checklist Version 2.1", February 13, 2004.
- [24] Perme, D., et al: "Integrating Air and Ground Operations within a Common Battle Management Language", Paper 05S-SIW-148, Spring 2005 Simulation Interoperability Workshop, San Diego, CA, April 2005.
- [25] Petty, M., et al: Findings and Recommendations from the 2003 Composable Mission Space Environments Workshop, Paper 04S-SIW-004, Proceedings of the IEEE 2004 Spring Interoperability workshop.
- [26] Petri, D., "OSI Model Concepts", MCSE World, http://www.petri.co.il/osi_concepts.htm
- [27] Petroski, Frank (MITRE), "Blue Force Tracking COI Service: Implementing the Net-Centric Data Strategy", briefing, DMSO M&S COI Kickoff, 16 Nov 2004.
- [28] Pullen, J. et al: "Using Web Services to Integrate Heterogeneous Simulations in a Grid Environment", Proceedings of the International Conference on Computational Science, Krakow, Poland, 2004.
- [29] Reichenthal, S.: "The Simulation Reference Markup Language (SRML): A Foundation for Representing BOMs and Supporting Reuse", 02F-SIW-038, Fall Simulation Interoperability Workshop, Orlando, Florida, September 2002.
- [30] The Synthetic Environment Data Representation and Interchange Standard (SEDRIS), <http://www.sedris.org/index.htm>
- [31] Timian, D. et al: "Report Out of the C4I Study Group", SISO Simulation Interoperability Workshop. Paper 00F-SIW-005, Orlando, FL, September 2000.
- [32] Todd, Mike (OSD(NII)): "Meeting the Net-Centric Challenge: Industry Recommendations", briefing, NCES workshop #2, 5 Mar 2004.
- [33] Tolk, A.: "Avoiding Another Green Elephant - A Proposal for the Next Generation HLA Based on the Model Driven Architecture, 02F-SIW-004, Fall Simulation Interoperability Workshop, Orlando, Florida, September 2002.
- [34] Tolk, A., "Metamodels and Mappings - Ending the Interoperability War", 2004 Fall SIW, Orlando, FL, September 2004.
- [35] U.S. Army Training and Doctrine Command: TRADOC Pamphlet 525-3-0.1, The United States Army Future Force Battle Command (C4ISR) Concept, March 2003.

- [36] U.S. Joint Forces Command: Capstone Requirements Document Global Information Grid (GIG), 30 Aug 2001.
- [37] U.S. Joint Forces Command: Conversion of the Joint Command and Control Capability Operational Requirements Document (ORD) to a Capability Development Document (CDD), Final Draft ver 2.2, 02 August 2004.
- [38] World Wide Web Consortium: Extensible Markup Language (XML) 1.0 (third Edition), <http://www.w3.org/TR/2004/REC-xml-20040204/>, 2004.
- [39] World-Wide Web Consortium, <http://www.w3.org/>.

Remarks

This paper is the result of an independent study conducted by Mrs. Leslie Winters at the Virginia Modeling Analyses and Simulation Center under supervision by Dr. Andreas Tolk within the M&S Ph.D. program of Old Dominion University, Norfolk, VA. It reflects the results based on academic research as conducted by the study team and does not necessarily represent the standpoint of affiliated organizations.

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